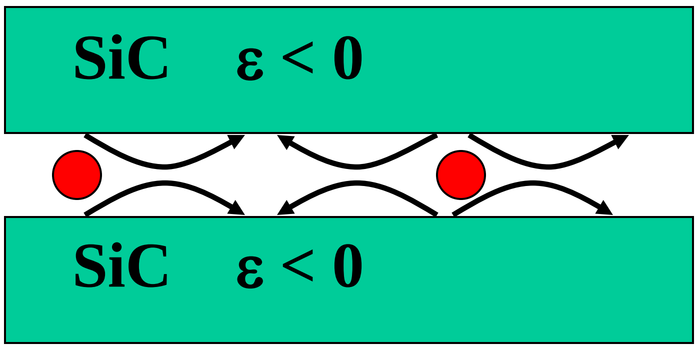
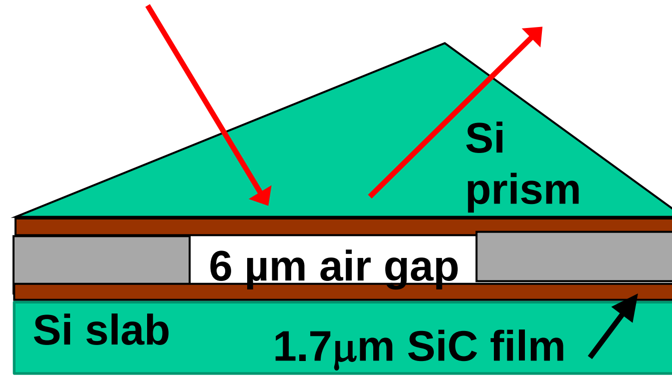
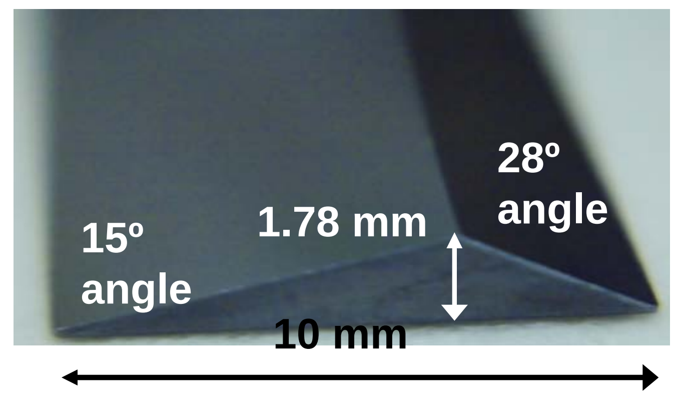
Surface wave accelerator based on Silicon Carbide for Beam Diagnostics

Gennady Shvets, University of Texas at Austin







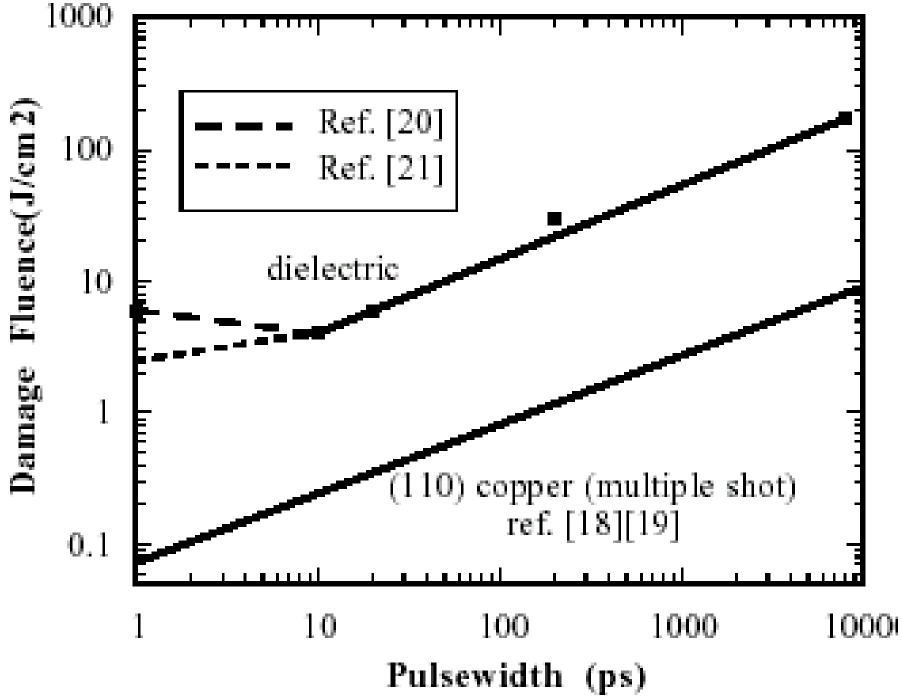
<u>With</u>: Dmitriy Korobkin, Burton Neuner III, Sergey Kalmykov, Chris Fietz

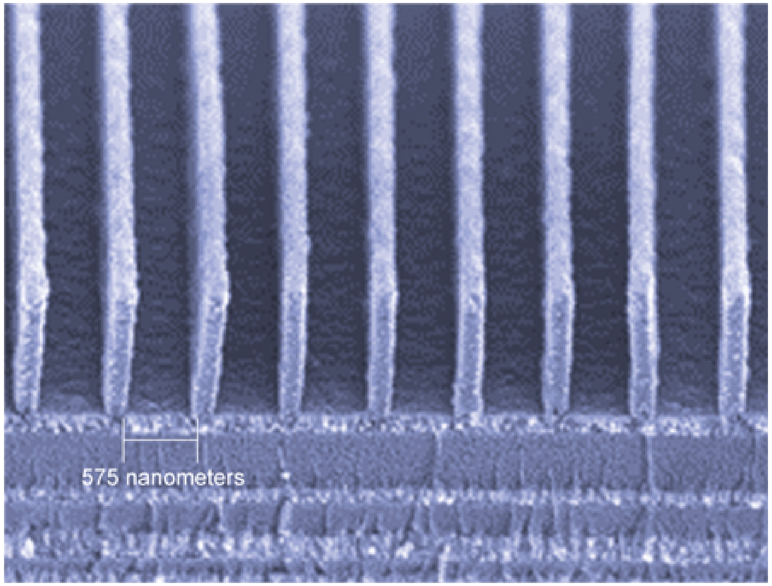
ATF Users Workshop, ATF/BNL October 7, 2010

Outline of the talk

- **Limitations of the conventional approaches: metals break down and dielectrics charge up!**
- **Electromagnetic properties of the Surface Wave Accelerator Based on SiC (SWABSiC)**
- **Cold tests of SWABSiC at UT**
  - **Prism coupling: Kretschmann configuration**
- **SWABSiC: What Can be Done at the ATF**
  - **Possible diagnostics of the beam misalignment**
  - **Beam-driven wakefield accelerator**
  - **Two-stage experiment: one CO2-driven SWABSiC prebunches the beam, the other one diagnoses!**

Laser and Beam Damage: Dielectrics vs. Metals vs. Semiconductors





From Du and Byer (1999).

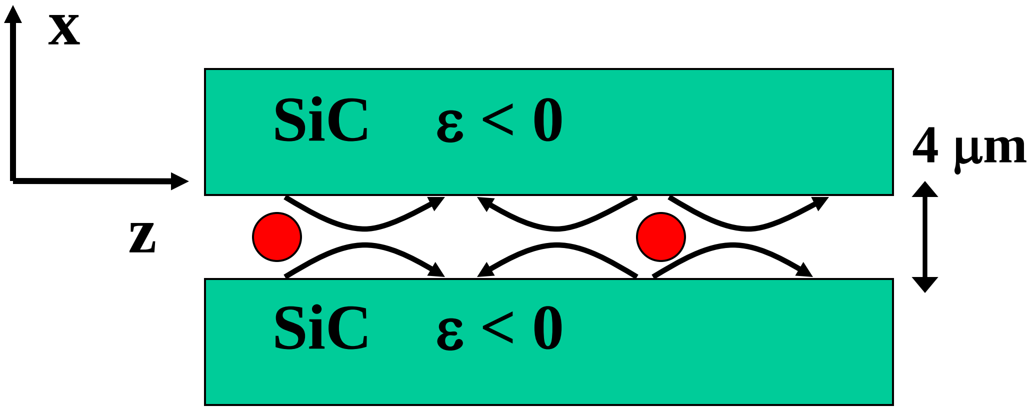
Most measurements at 0.8-1 micron wavelength

Livermore's diffraction gratings based on multilayer dielectric reflectors → no gold to avoid damage

(Most) Dielectrics + electron beams = charging

Pure semiconductors → few free carriers + full valence band

Surface-wave accelerator driven by a high-power CO_2 laser

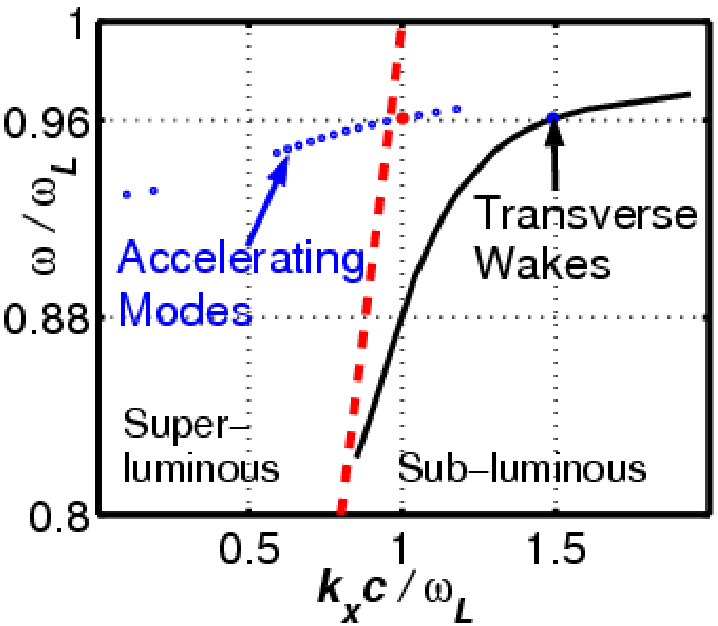


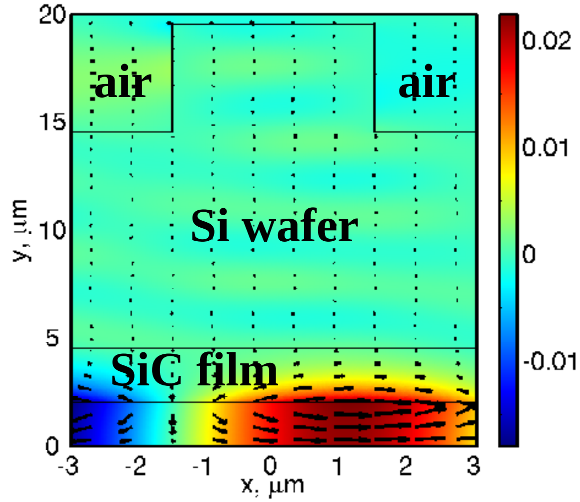
SiC/vacuum SPP's are excitable by widely available tunable CO_2 laser

Kalmykov, Polomarov, Korobkin, Otwinowski, Power, and Shvets, Phil. Trans. Royal Soc. **364,** 725 (2006); AAC'08 Conf. Proc., p.538 (2009).

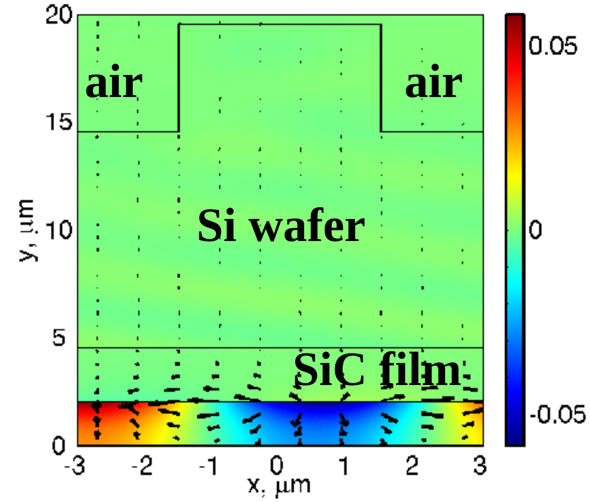
- **Supports ω = kc mode → can accelerate relativistic particles**
- **Near field (small gap) → attractive ratio E_z/E_x**
- **Acceleration by surface phonon polaritons (SPP)**
- **Application: injector into laser-plasma accelerator**
- **Cherenkov diagnostics for compressed ATF beam?**

Electromagnetic modes of the Surface Wave Accelerator Based on SiC (SWABSiC)





Accelerating mode @10.708 µm



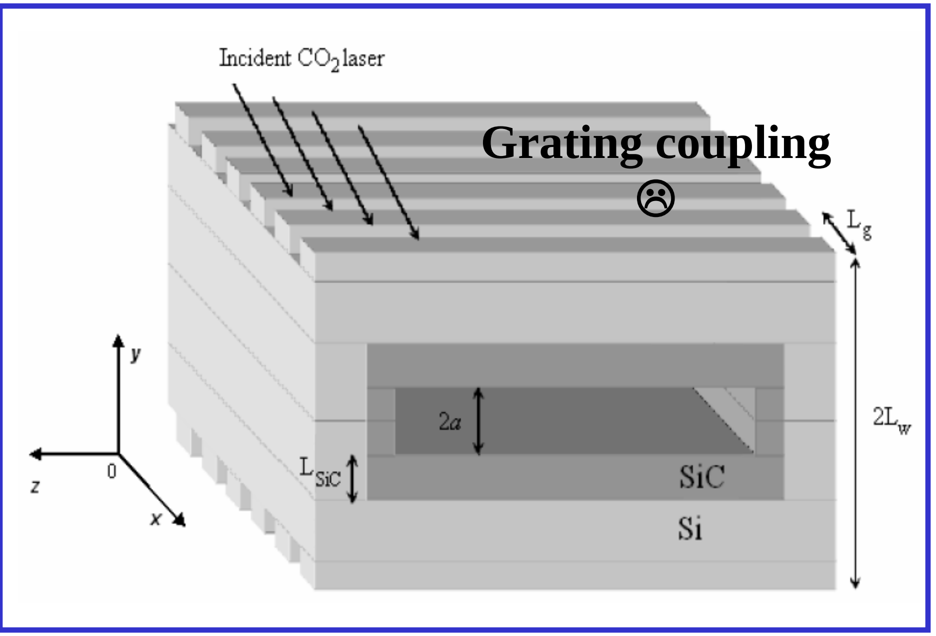
Parasitic transverse wake @10.708 µm

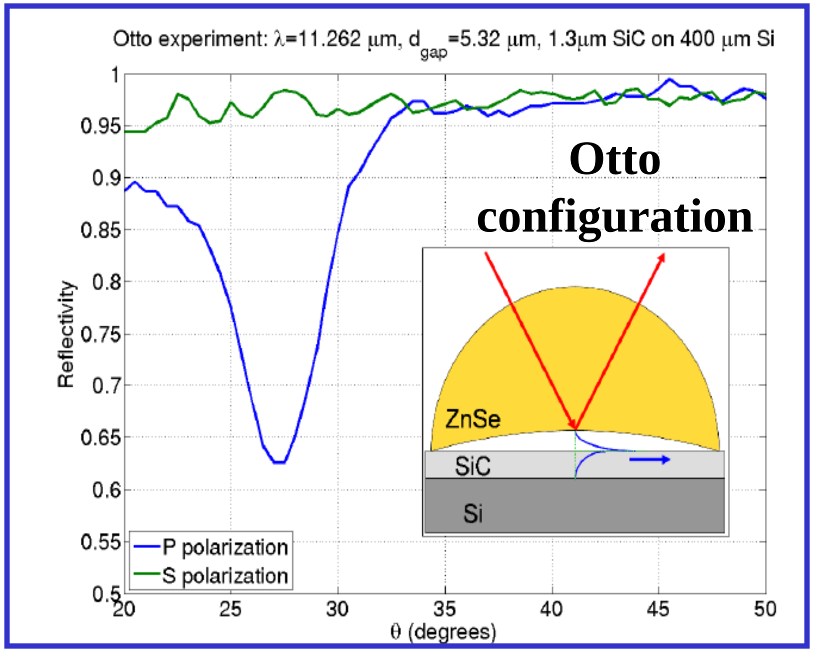
Silicon Carbide: low-loss polaritonic material with $\varepsilon < 0$ in mid-IR ($\omega_L = 2\pi\, c/10.3\ \mu m$, $\omega_T = 2\pi\, c/12.5\ \mu m$)

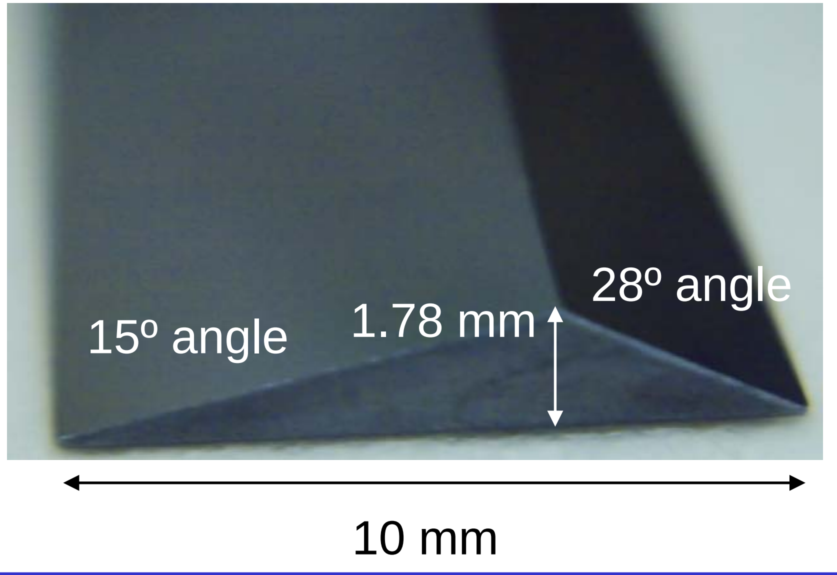
$$\varepsilon = \varepsilon(\infty)\frac{\omega_L^2 - \omega^2 - i\gamma\omega}{\omega_T^2 - \omega^2 - i\gamma\omega}$$

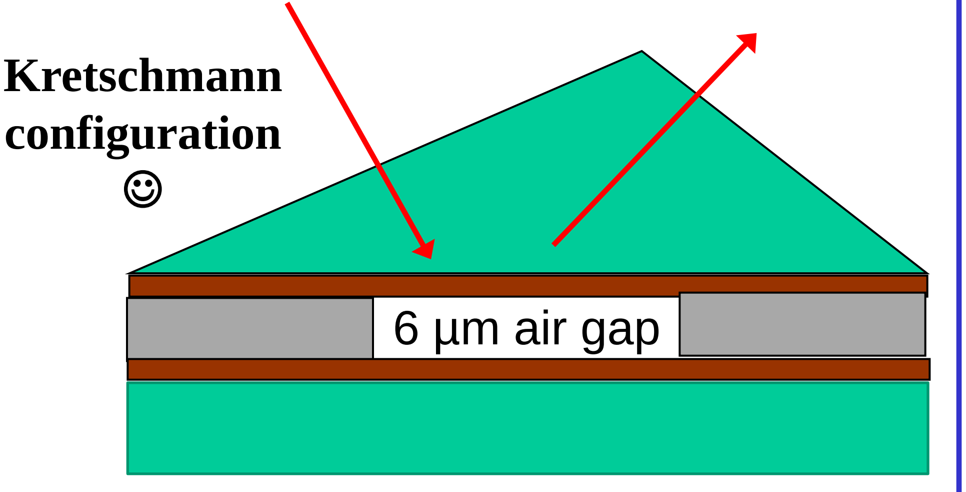
Coupling and propagation challenge: how to couple 10.6 µm radiation into a 4 µm hole → not only the hole small, the mode's symmetry is not good for coupling!

Coupling: what works and what does not

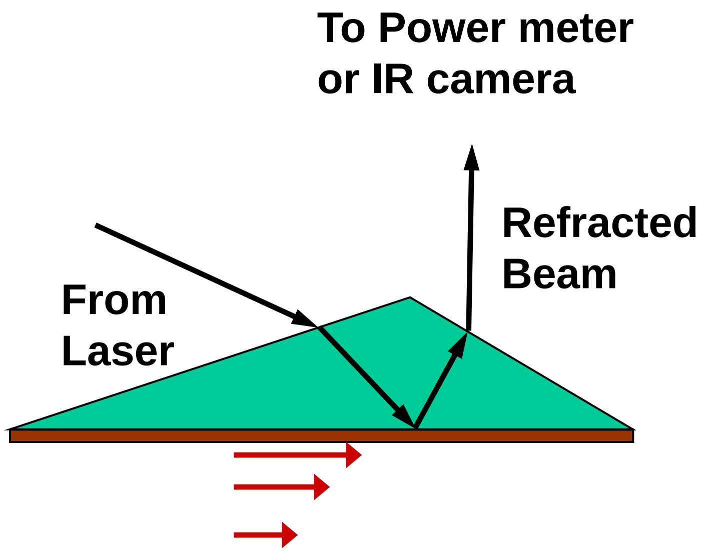


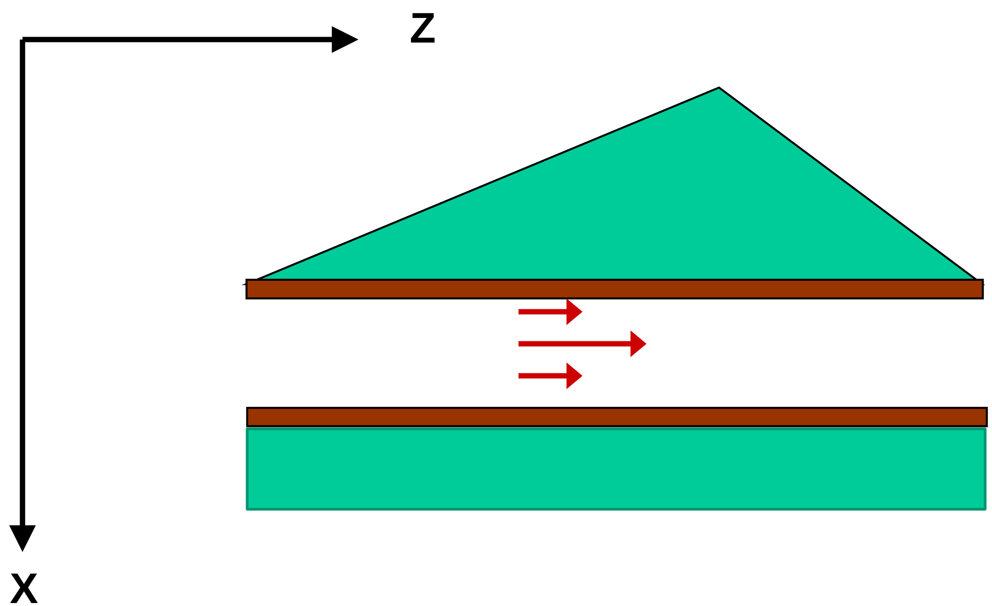






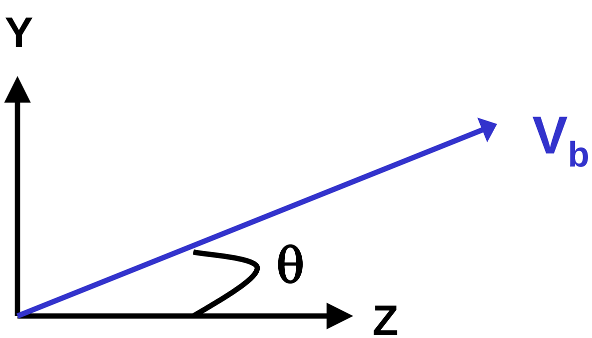
Single and double interface SWABSiC





Single-interface (SiC/air) SWABSiC → v_{ph} < c wakes

Double-interface (SiC/air/SiC) SWABSiC → v_{ph} >< c wakes



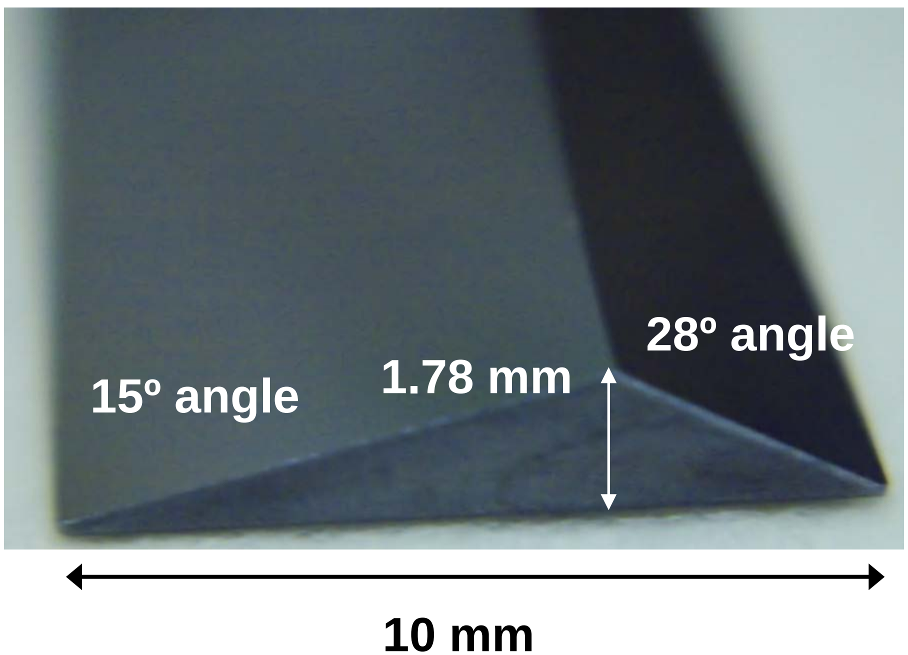
Cherenkov configuration for single-interface SWABSiC

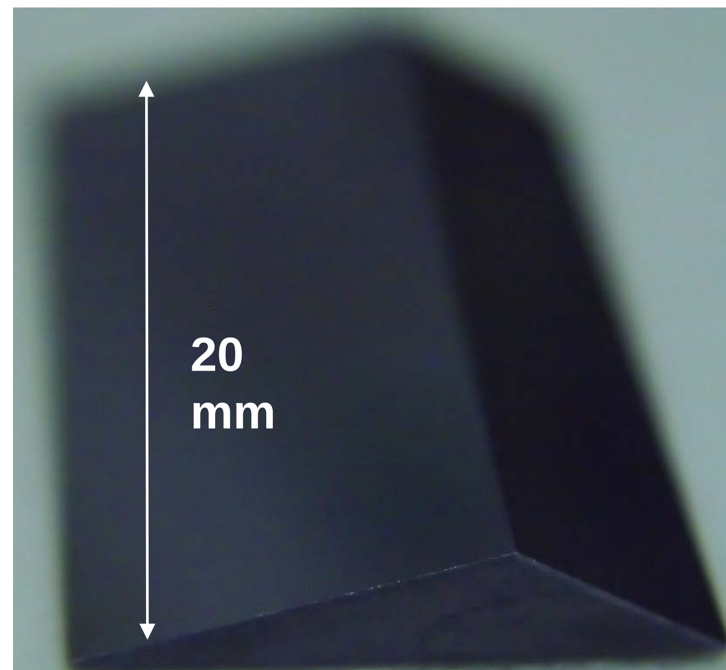
Si Prism + SiC Film Fabrication

•Step 1: cutting Si discs (D=5cm, t=5mm) into 22x12x5 mm “bricks”

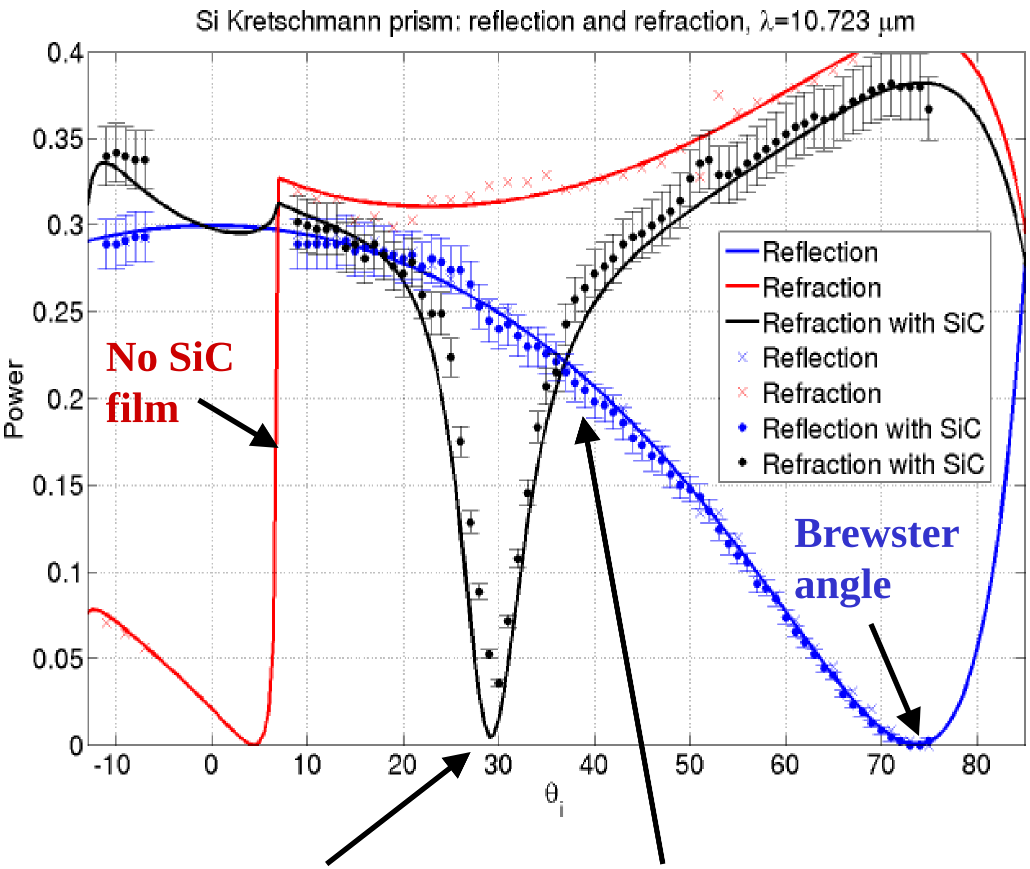
•Step 2: growth of 1.7 μm SiC in Lyon, France

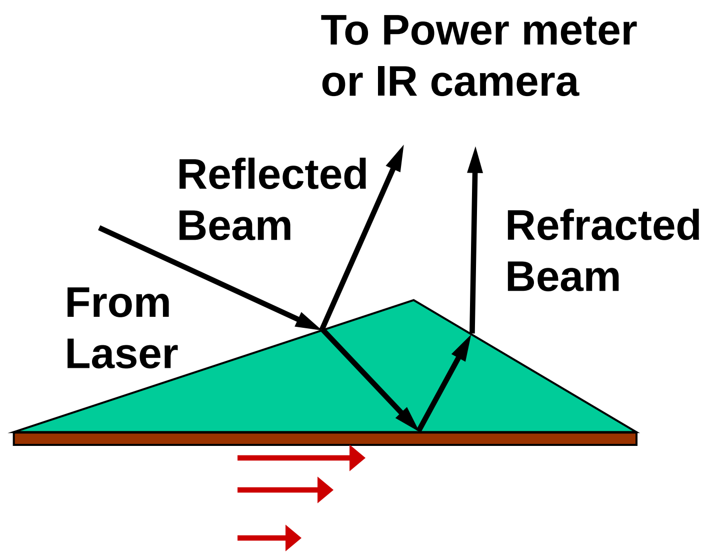
•Step 3: cutting Si “bricks” into prisms (ISP Optics)

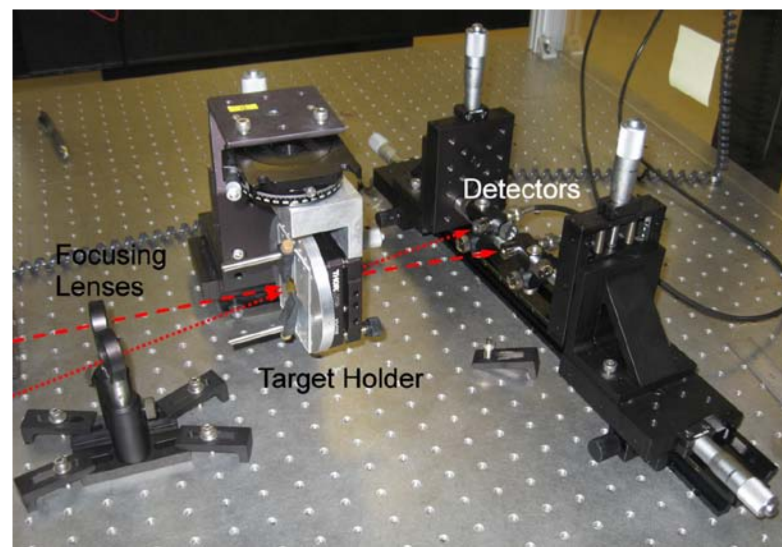


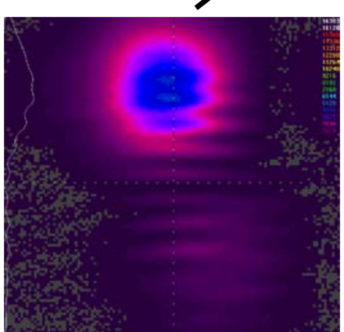


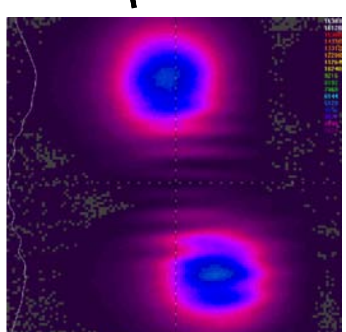
Sub-luminous SPP at SiC/air interface



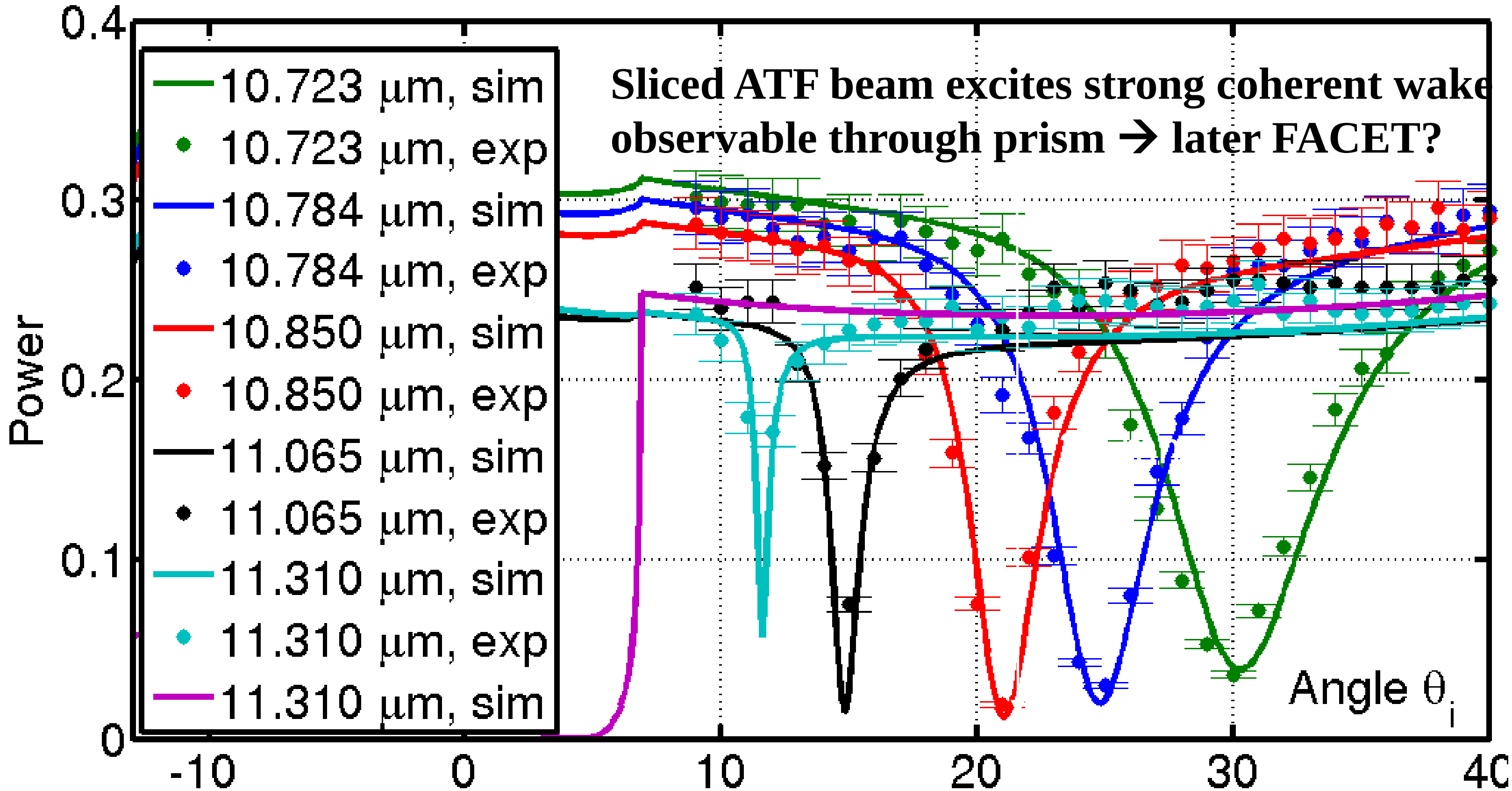


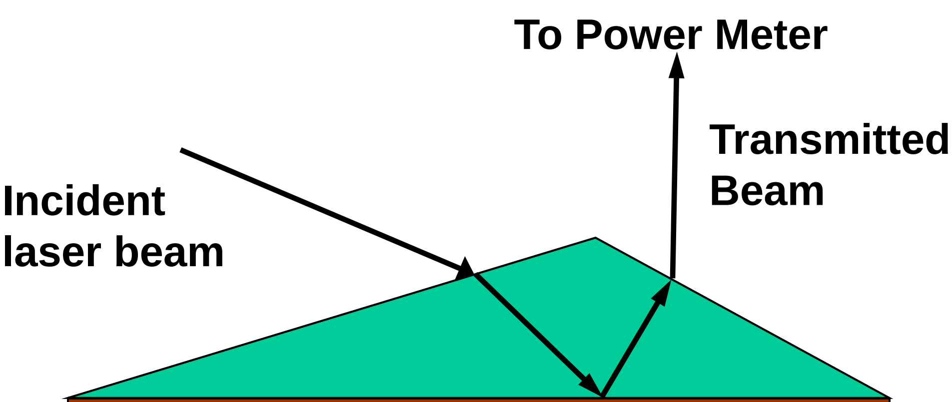






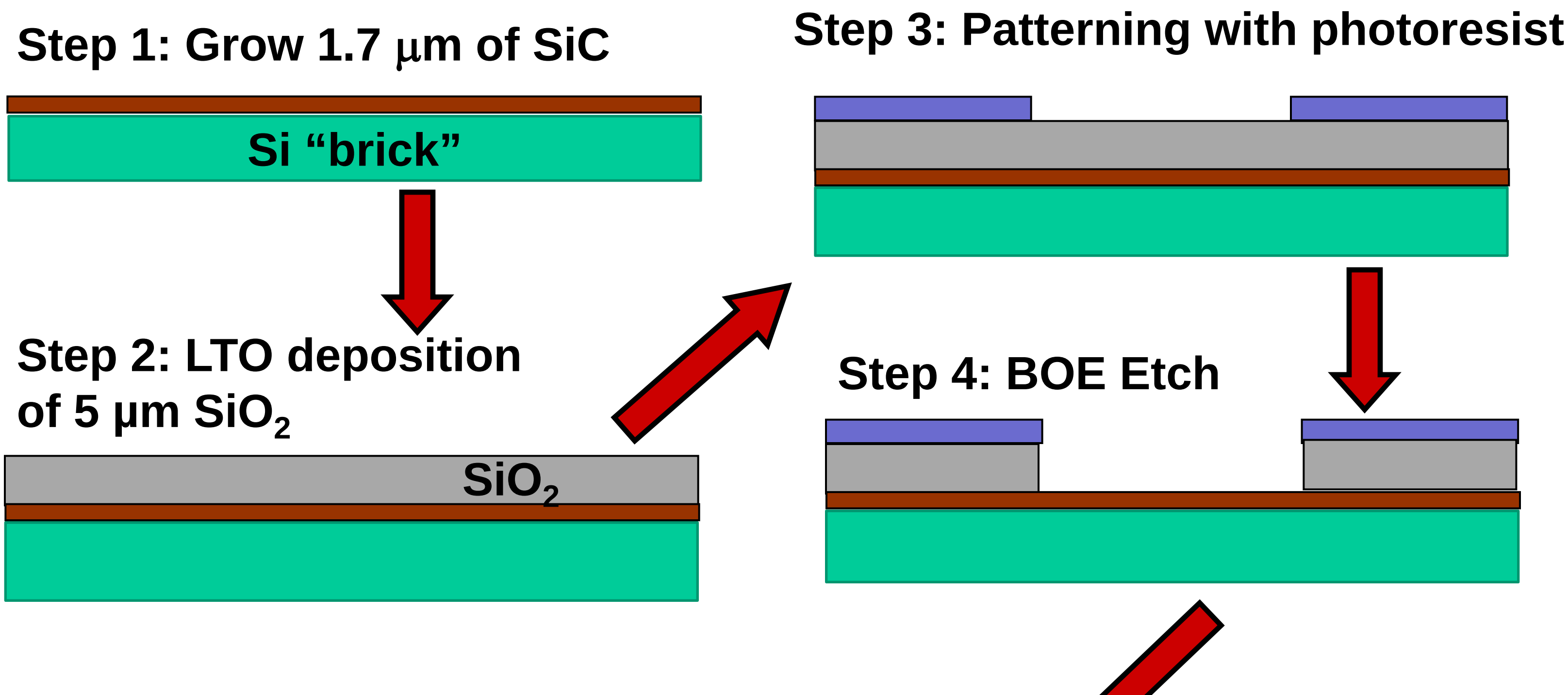
Single-interface SSPs: different λ’s



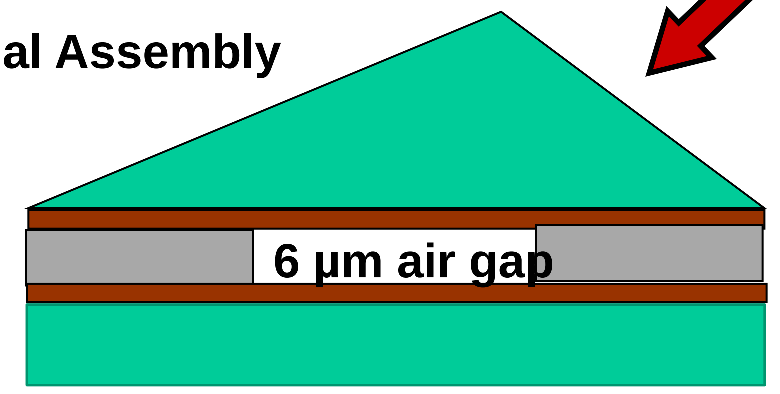


- Narrow beam propagating at small angle to the prism’s center plane gets modulated by a CO_2 laser
- Prebunched beam passes through the second SWABSiC → diagnostics of the bunching

SWABSiC: two interface SPPs



Step 5: Final Assembly



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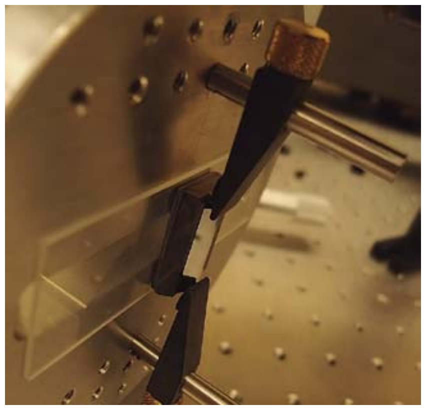
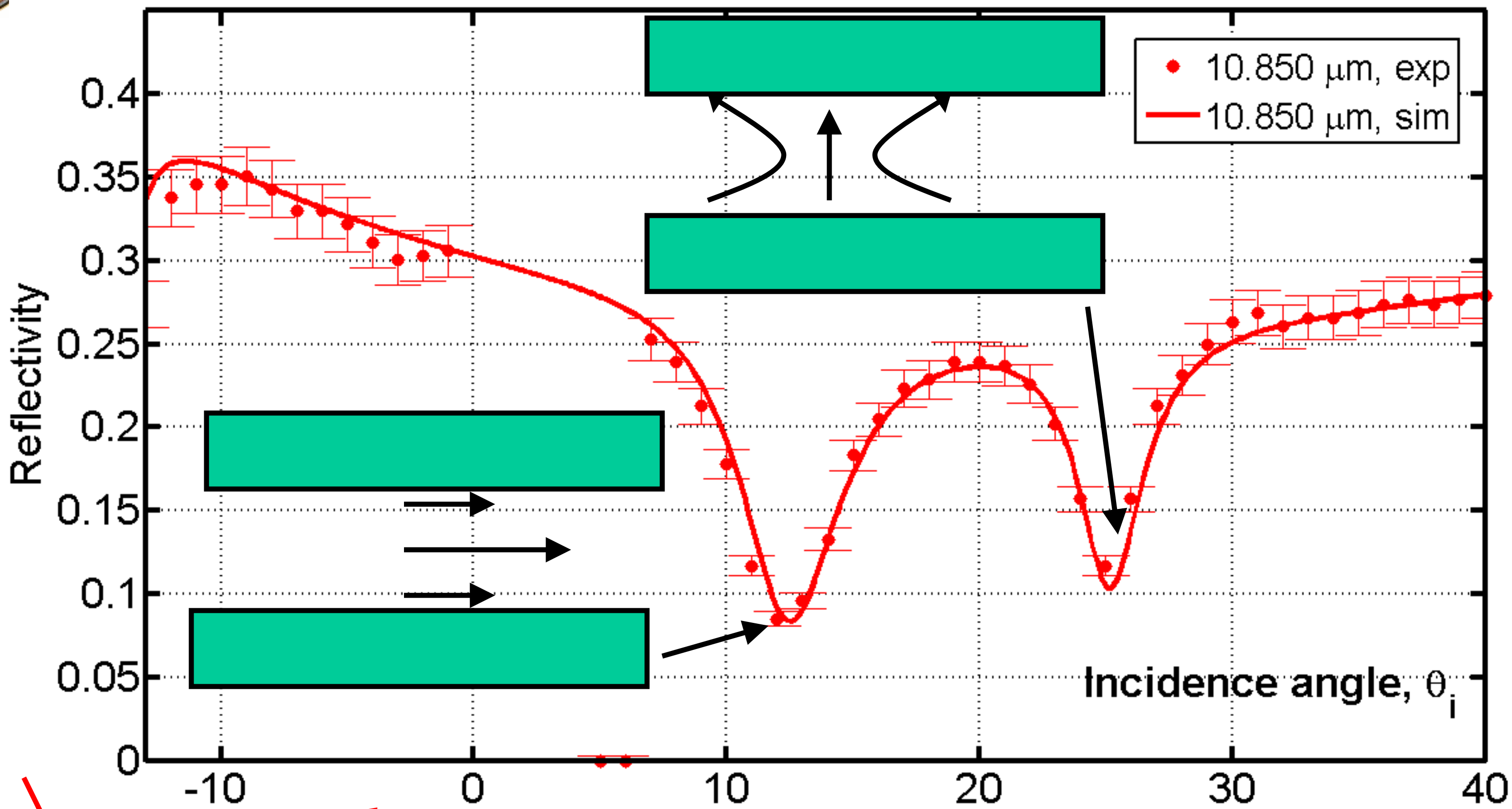
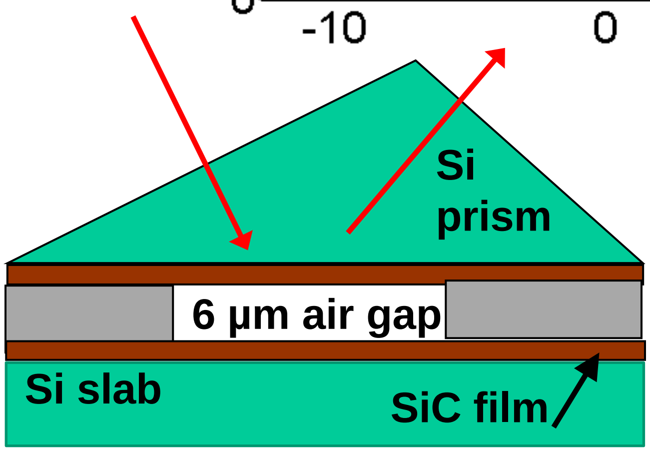


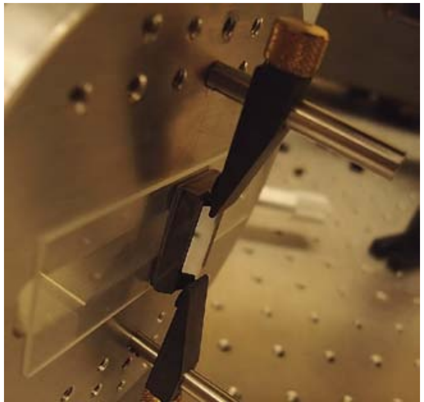
Longitudinal and Transverse Wakes



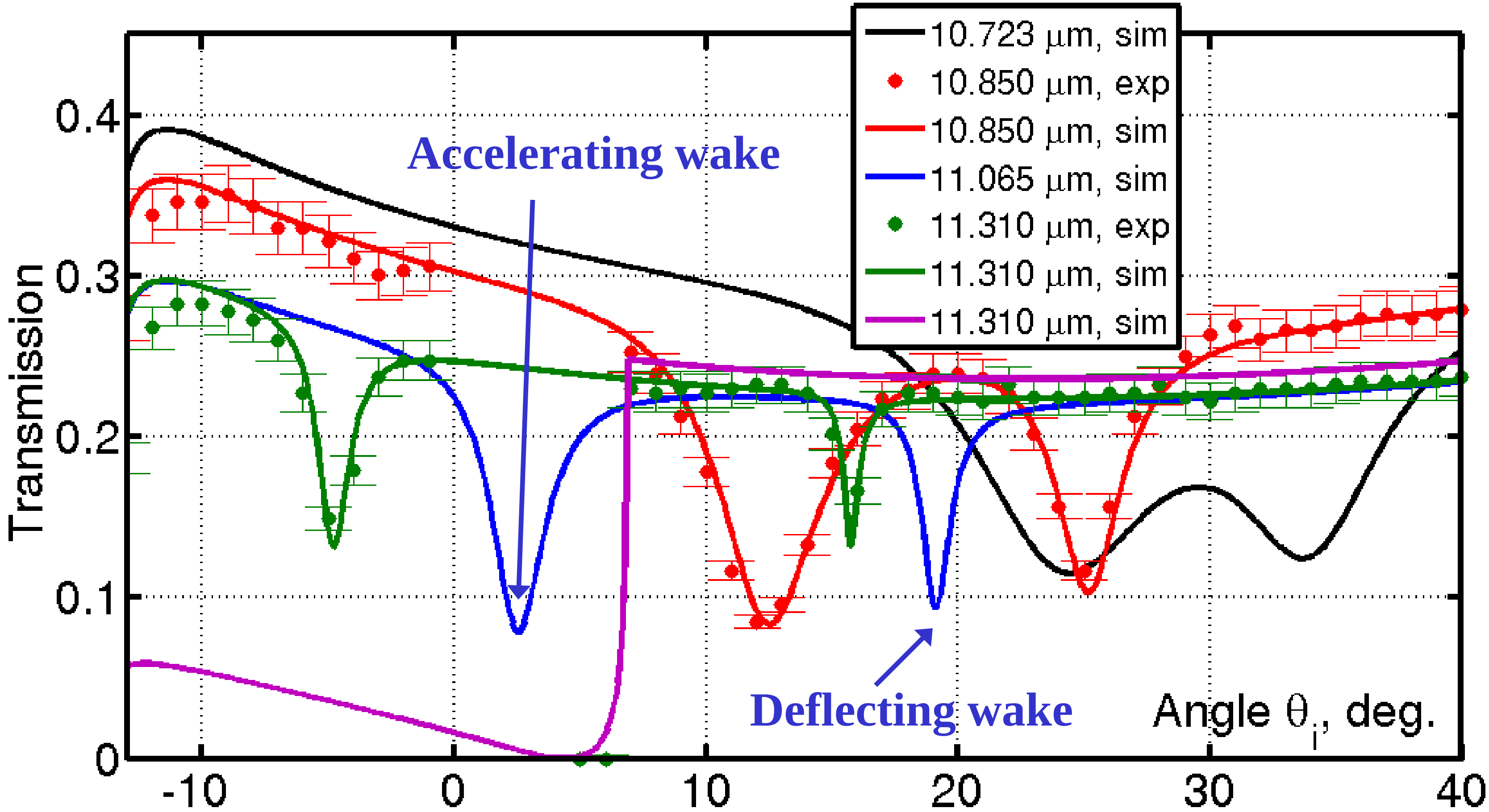


Left: schematic

Right: target assembly

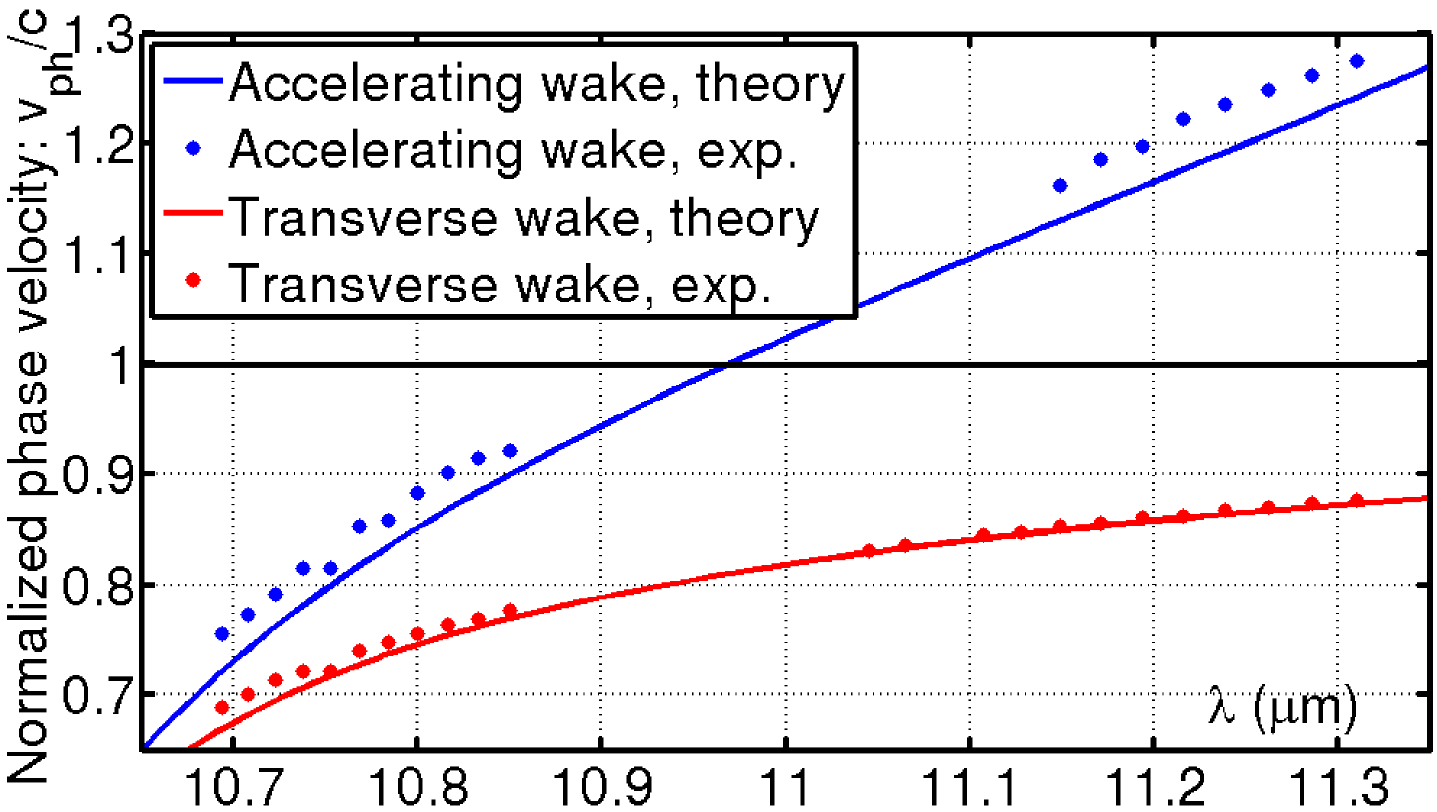


Guided Wakes for all Wavelengths



- **Both accelerating (good) and deflecting (parasitic) wakes are experimentally observed**
- **Need a σ_z = 10-20 μm compressed or sliced ATF beam**

Phase Velocities of Wakes



- **Only two transversely confined modes: accelerating (good) and deflecting (parasitic) wakes**
- **Both experimentally observed in cold tests**
- **Measuring beam centroid's position at ATF**

Proposed set of ATF Experiments

- **Investigation of the all-semiconductor structure charging by the beam's impact: easy!**
- **Breakdown or now breakdown with a MW CO2 laser? Relatively easy (we only have a 1W laser at UT)**
- **Generation of transverse and longitudinal wakes by a compressed (30 microns) beam: both in single-interface and double-interface geometries**
- **Self-modulation of a long beam inside SWABSiC → need to do more simulations**
- **Beam diagnostics (including centroid's displacement) by monitoring transverse and longitudinal wakes**
- **Two-stage SWABSiC: prebunching of the long beam using the CO2 laser followed by Cherenkov emission from the second SWABSiC structure**

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